Cornwell & Williams

Steel Highway Bridges with Reinforced Concrete Floors

Civil Engineering

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STEEL HIGHWAY BRIDGES WITH REINFORCED CONCRETE FLOORS

BY

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AND

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THESIS

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June 1, 1910

This is to certify that the thesis of EARL ZINK CORNWELL and GLENN RICHARD WILLIAMS entitled Steel Highway Bridges with Reinforced Concrete Floors is approved by me as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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Instructor in Charge.

Approved:

Ira O. Baker.
Professor of Civil Engineering.

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ART. 1. INTRODUCTION.

The rapid increase in the use of reinforced concrete as a building material in the last twenty years, due in part to the growing scarcity of timber and the consequent high price of suitable lumber and in still greater part to the durability and comparative cheapness of the reinforced concrete itself, has made it necessary to change old methods of design and to make many experiments in order to obtain information for use in designing with this new building material. This is especially true of steel highway bridges with reinforced concrete floors, since few, if any, such floors were used in this class of bridge prior to the year 1900.

As concrete floors are much heavier than wood floors, it is necessary to design the trusses, floor-beams, and stringers of a bridge with concrete floors, to carry a larger dead load than that of a bridge with wood floors.

The dead load to be assumed for designing a bridge with wood floors is known very accurately; but it is not known for bridges with concrete floors, and consequently, the dead load assumed is frequently very much in error, often making a complete redesign of the bridge necessary.

The object of this thesis, therefore, is to obtain some empirical formulae for obtaining the dead load to be used in designing steel beam, pony, and truss bridges with reinforced concrete

floors; also, to compare such bridges with those having wood and steel floors.

Whenever the term highway bridges is used in this thesis it signifies a structure which is subjected to the ordinary traffic of country roads, no car tracks or foot walks being upon it.

ART. 2. DETERMINATION OF TYPE OF BRIDGE.

Bridges should be designed to carry the heaviest loads that will pass over them, and they should be wide enough to allow uninterrupted passage of traffic. The greatest moving loads that come on highway bridges are traction engines; and therefore, these bridges are classified according to the size of engine which they are designed to carry. Class A bridges are designed for 20-ton, and Class B bridges for 15-ton engines. In addition to the traction engine, a Class B bridge is designed to carry a moving or live load of one hundred pounds per square foot of floor surface, which cannot act at the time the engine is on the bridge. If the concrete floor acts with sufficient rigidity to distribute the weight of an engine over the entire panel, it is evident that a Class B bridge is strong enough to carry a 20-ton engine, since the increased load per square foot due to the extra five tons of engine load, is, for a 16' x 10' panel: $(5 \times 2{,}000)/(10 \times 16) = 62.5$ pounds per square foot, or 37.5 pounds less than the 100 pound live load designed for.

Different width of roadways are required for different localities, depending on the character and amount of traffic which is to pass over the bridges. A mean and quite generally adopted width is sixteen feet.

In view of the above mentioned facts only Class B bridges with 16-foot roadways will be considered in this thesis.

ART. 3. COMPARISON OF WOOD WITH CONCRETE FLOORS.

Owing to the variation in the cost of wood and concrete floors in different parts of the country, due principally to local conditions, it is very difficult to make even an approximate estimate as to the relative merits and defects of wood and concrete floors for highway bridges. For instance, oak lumber is about 200 per cent higher on the Atlantic Coast than on the Pacific. The cost of cement is more uniform, but the cost of sand, gravel, and broken stone naturally varies in different parts of the United States.

The Illinois State Highway Engineer states that wood floors on highway bridges in this state last six years on the average, and that if reinforced concrete floors last 2 1/2 times as long, or say 15 years, the cost per annum, will be the same for both. This also includes the cost of the extra weight required in the trusses. As reinforced concrete has not been in use for a period of 15 years, it cannot be stated as a fact that such floors will wear for that length of time, but from all present indications of wear, they will be serviceable for a much longer period, say 20 years, at least. The quality of floor depends on the quality of materials used and the strictness with which the work is inspected.

As lumber is advancing steadily in price with the depletion of the supply and in all probability will continue to do so for several years, and as the price of concrete steadily decreases, due to the use of improved machinery for mixing, more unifrom and cheaper cement, and more economic

methods of design, it seems as though concrete will be used almost exclusively for bridge floors in the near future, because it is more economical.

There is no doubt but that concrete makes a better floor for bridges than wood, as it is heavier, stronger, and less noisy. It has been shown, by tests with extensometers, that there is practically no vibration of the floor when vehicles passed over the bridges, and that the stress in some of the truss members did not exceed the live load stress, showing that the floor absorbed the impact stress. It will probably be shown in the near future that there is very little impact in any of the members of bridges with concrete floors, but it remains to be seen whether this change will affect the design of the trusses. Even if the rigidity of the floor never affects the design of the truss it is certain that a concrete floor is much more satisfactory than a wooden floor.

ART. 4. COMPARISON OF METAL WITH CONCRETE FLOORS.

A metal floor consists of a continous layer of metal on top of the joists and enough plain concrete over the top of this to cover the metal, stiffen it, deaden the sound and to give the required amount of strength, if necessary, to the floor.

There are many patented forms of metal on the market which are used for bridge floors, most of which are mentioned below.

1. Ordinary plates, angles, and bent plates are sometimes riveted together and serve as a support for the concrete. (See Fig. 1).

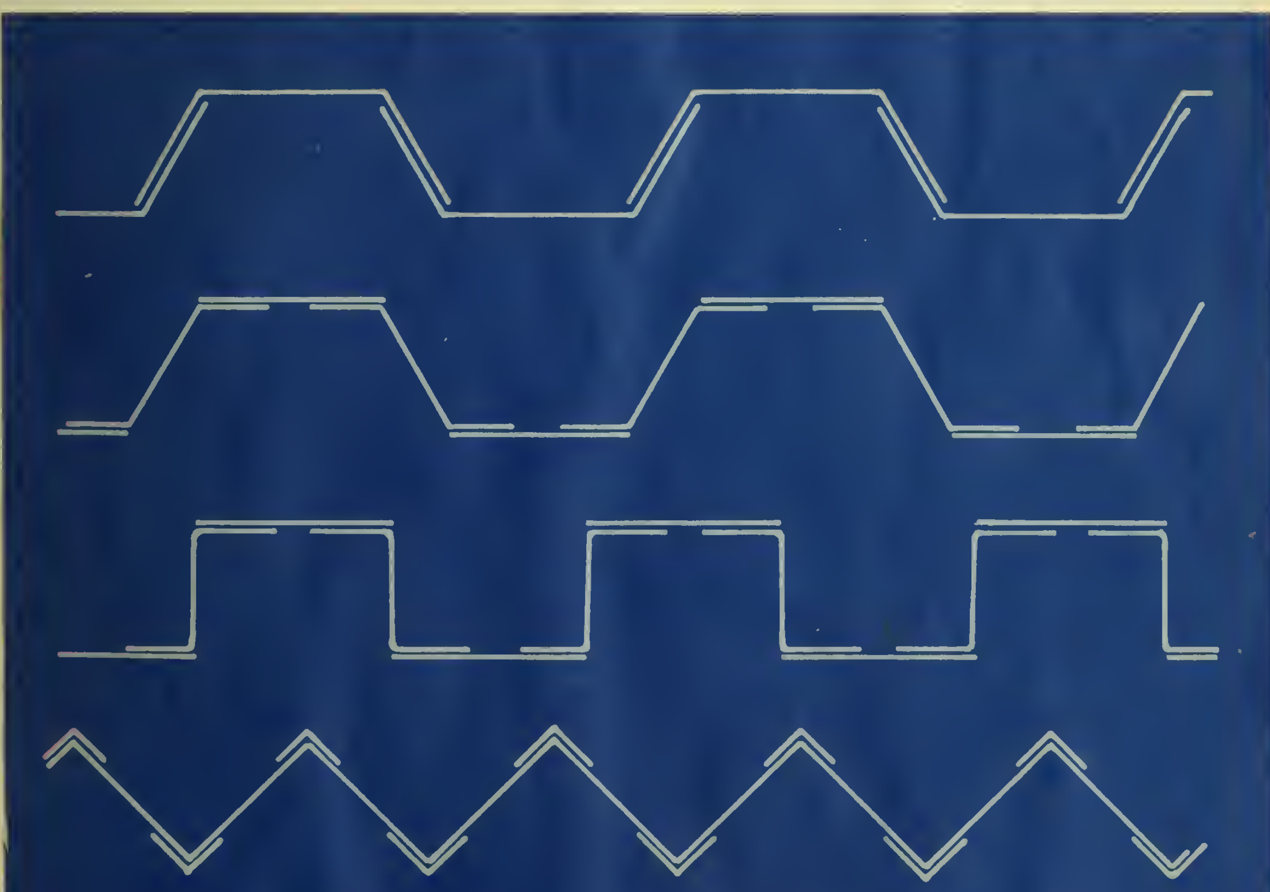

Fig. 1.

2. Buckle plates, manufactured by the American Bridge Co. are used frequently. (See Fig. 2).

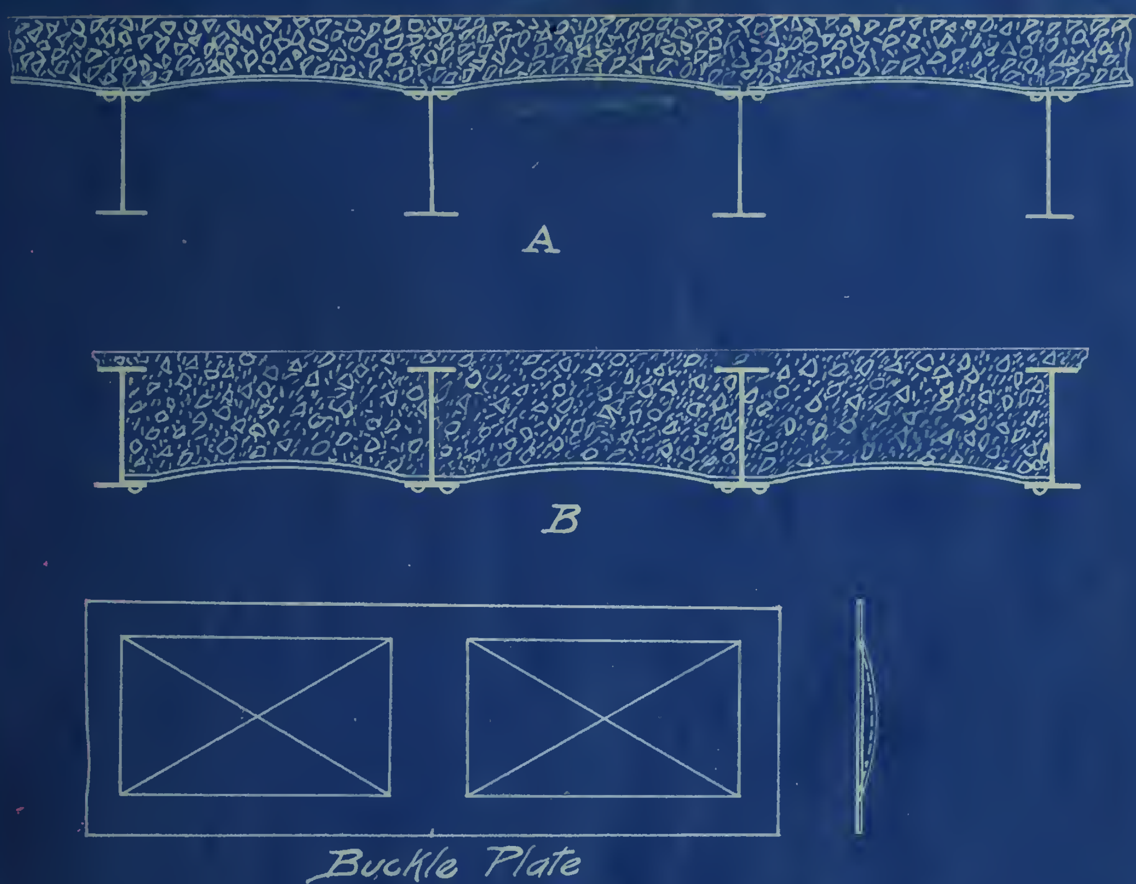

Fig. 2.

3. Patented forms of corrugated steel troughs are used. One form is known as the Buckeye Trough, (See Fig. 3, Page 8).

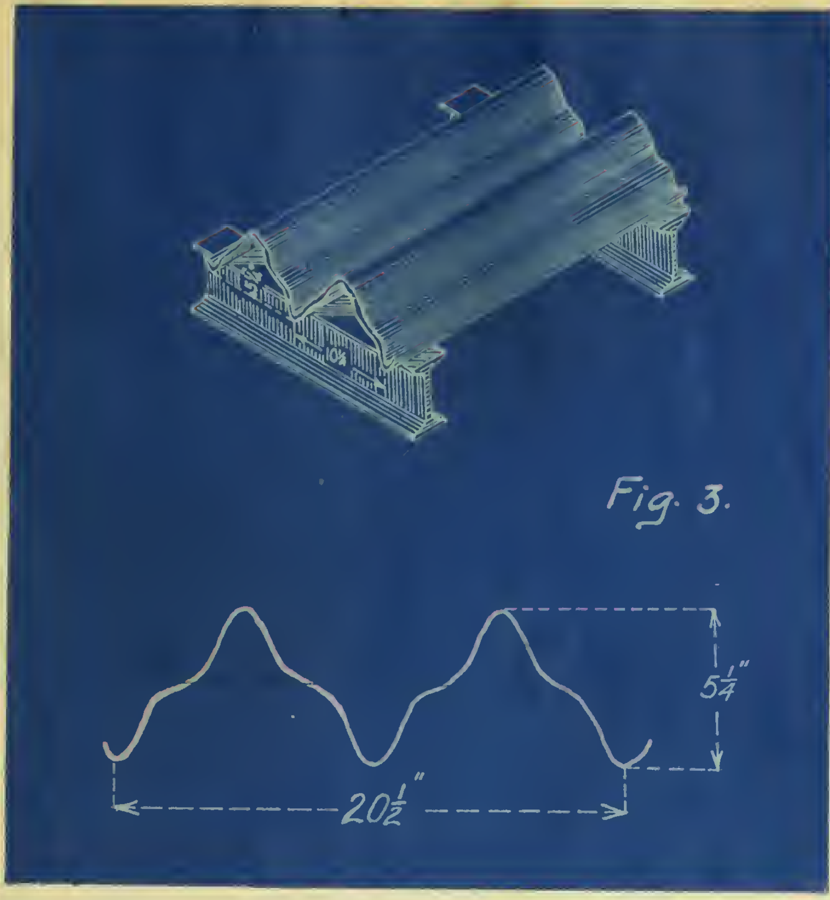

Fig. 3.

4. Another system of corrugated steel plates used is known as the Multiplex system. (See Fig. 4)

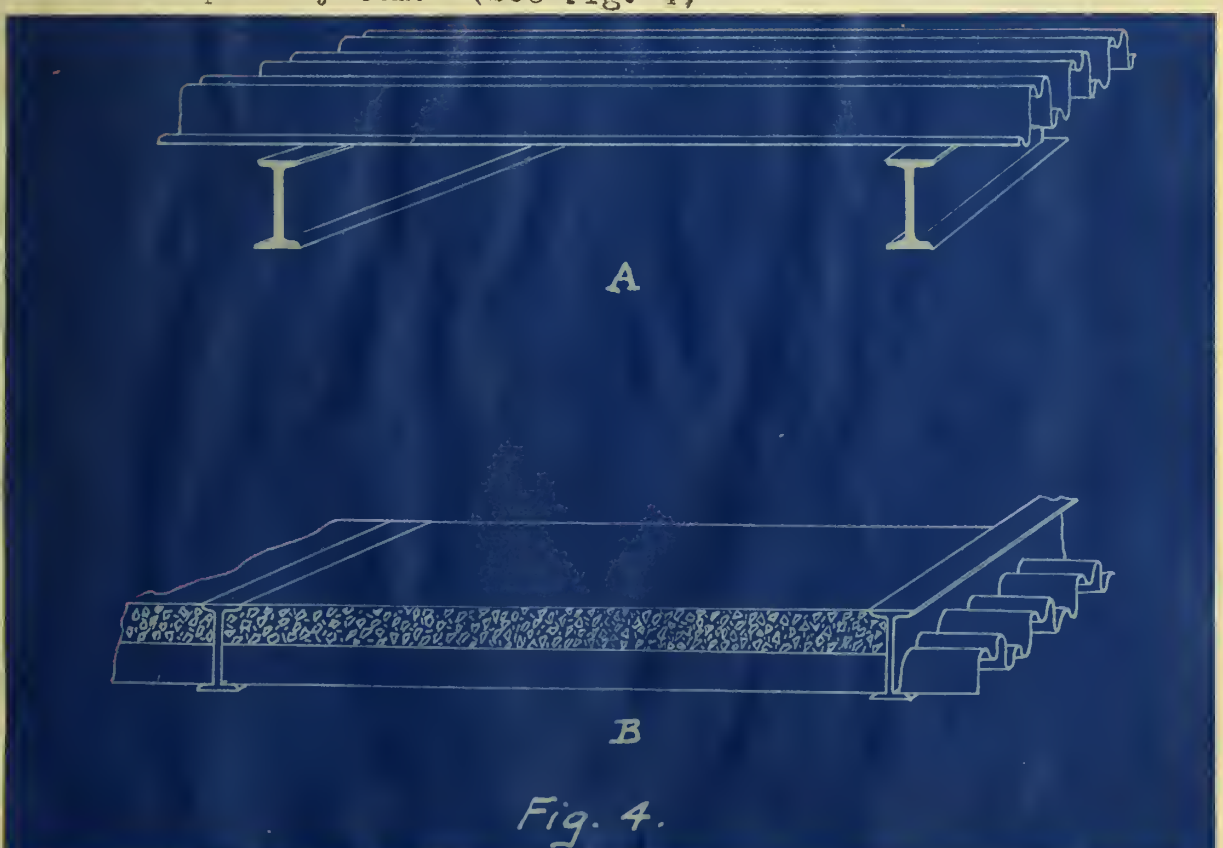

Fig. 4.

The weight of metal and reinforced-concrete floors is approximately the same, but owing to the greater amount of steel in the former its cost is higher than that of the latter. Moreover, it is claimed, with reason, that it requires skilled workmen to place a metal floor on a bridge; and even then the floor is not constructed in such a manner as to develope its full advantage over a reinforced concrete floor. Common laborers, however, can place a reinforced concrete floor nearly as well as skilled ones.

For country highway bridges, therefore, it would appear that reinforced concrete floors are better than metal floors because they are cheaper, and the class of laborers required to place them is more readily obtained.

ART. 5. COMPARISON OF VARIOUS TYPES OF CONCRETE FLOORS.

It is the purpose now to give a brief description of several types of concrete floors. For convenience they may be divided into two classes, namely:

Plain Concrete Floors.

Reinforced Concrete Floors.

Plain concrete floors are usually built in one of three ways:

1. The concrete is laid between the joists so that the bottom of the floor practically coincides with the bottom of the joists. The thickness of the floor must be great enough to give the required strength, and this naturally varies with the spacing of the joists. (See Fig. 5).

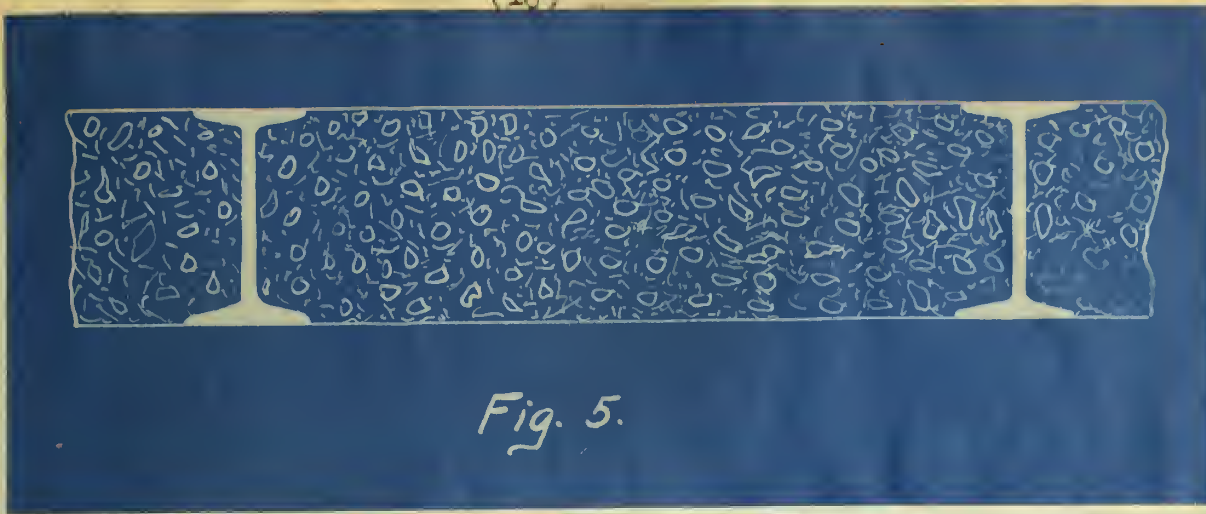

Fig. 5.

Drainage Details

Wood Floors —

Patent

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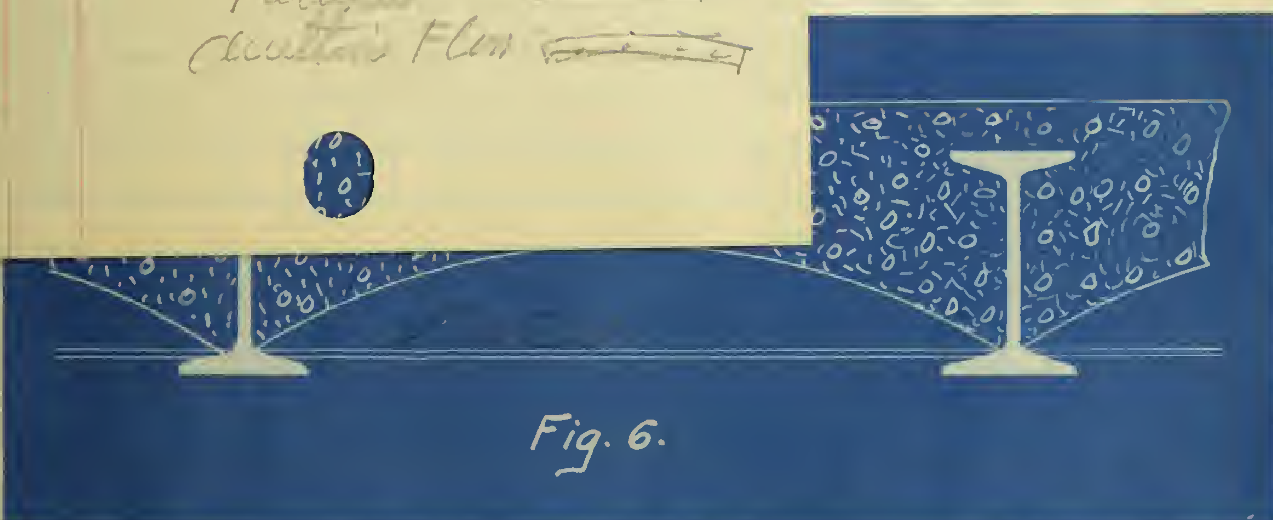


Fig. 6.

3. The concrete may be placed entirely on top of the joists and may be made in monolithic forms, (See Fig. 7), or the floor may be composed of slabs of suitable size, which may be either constructed in place on the joists, or placed on the joists and cemented together afterwards. (See Fig. 8).

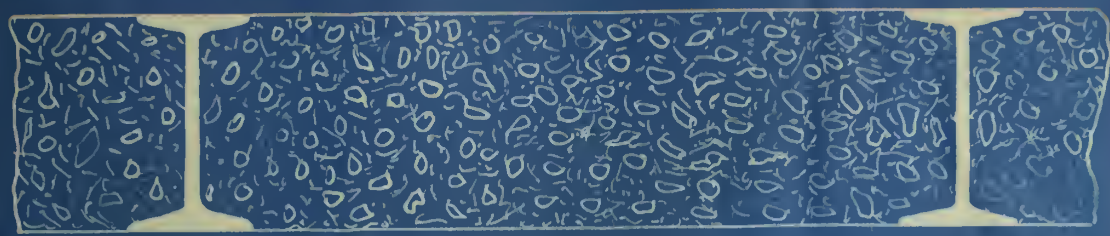


Fig. 5.

2. The concrete may be placed between the joists as described above but the bottom of the concrete may be arched as shown in Fig. 6. This is done for the sake of economy, but the increased cost of forms practically balances this saving in concrete. This form of floor is seldom used.

Fig. 6.

3. The concrete may be placed entirely on top of the joists and may be made in monolithic forms, (See Fig. 7), or the floor may be composed of slabs of suitable size, which may be either constructed in place on the joists, or placed on the joists and cemented together afterwards. (See Fig. 8).

Fig. 7.

Fig. 8.

Plain concrete floors are not in general use as the thickness of concrete required makes the cost unnecessarily high, and the dead load weight is very large. It is much more economical from all standpoints to use reinforced concrete.

REINFORCED CONCRETE FLOORS are constructed similarly to the last method described above. Slabs may be constructed with expanded metal or bars of some description embedded near the lower side of the slab, or the floor may be constructed as a whole with the rods or expanded metal embedded in different quantities, and by varying systems, according to the choice and judgement of the

EXPANDED METAL
WM. B. HOUGH CO. CHICAGO, U.S.A.

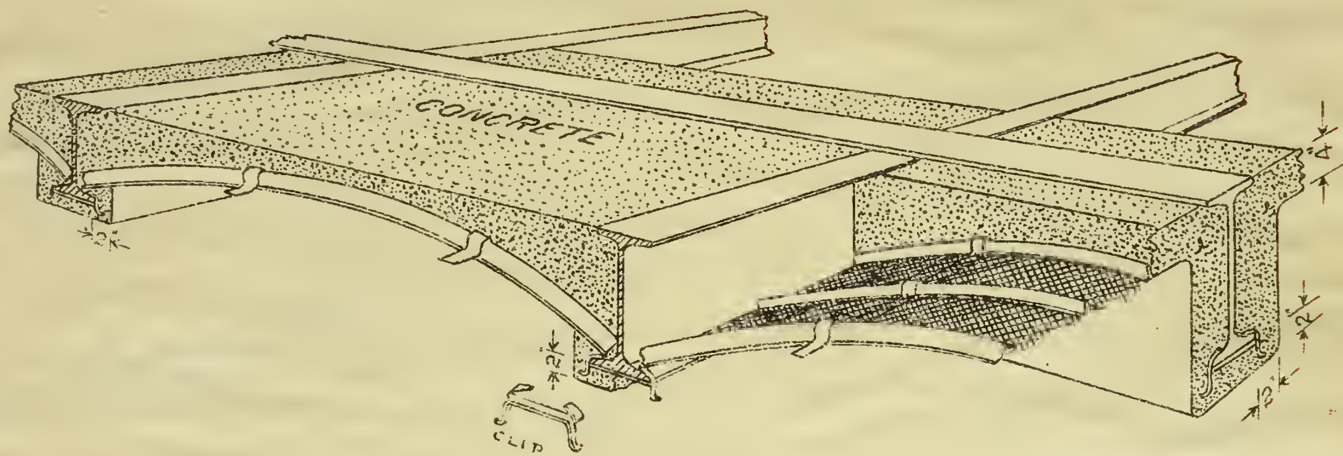


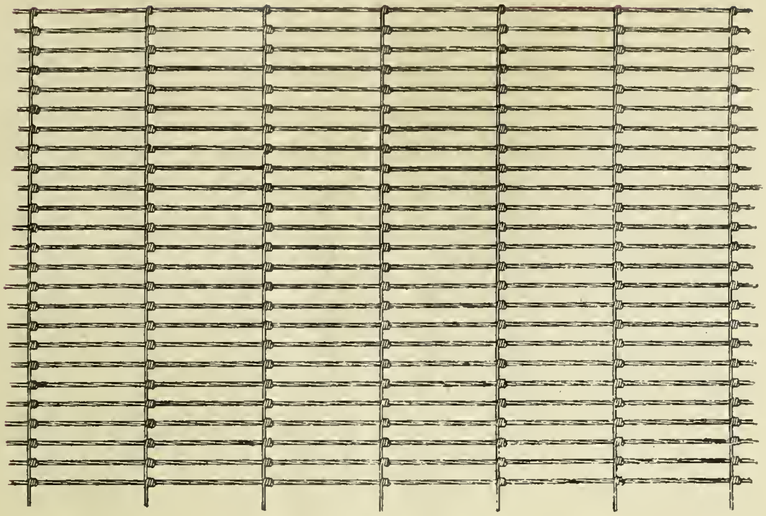
Fig. 9.

ROEBLING SEGMENTAL CONCRETE ARCH.

Roebling Construction Co.,

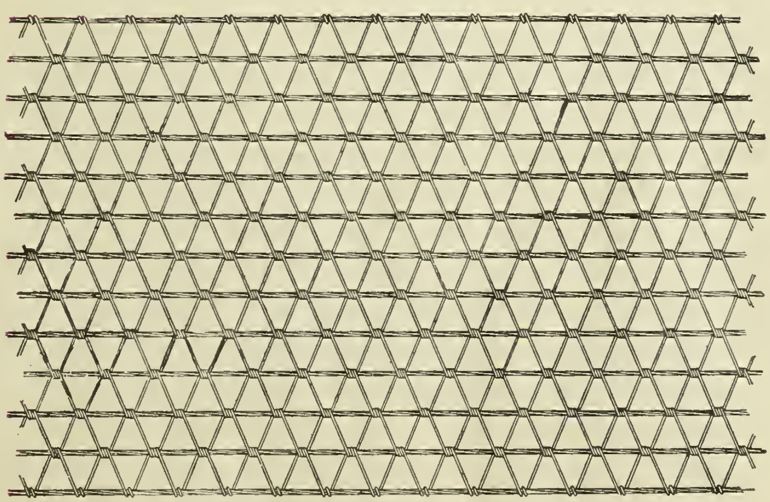
N. Y. CITY.

PATENTS APPLIED FOR.



Square Mesh Reinforcement.
Stranded Longitudinals.

PATENTS APPLIED FOR.



4-inch Triangular Mesh.
Reinforcement Stranded Longitudinals

Fig. 10.

designing engineer.

Expanded metal (See Fig. 9) and steel netting (See Fig. 9 and 10) are used considerably for floors for buildings, and some engineers use them for bridge floors. The New York State engineer in his annual report, " The Red Road Book", describes the use of the former in slab construction.

Bars, especially the patented bars known as the Ransome and Johnson bars, have been used for sometime for reinforcement. It is claimed by Ransome, the inventor of the twisted bar, (See Fig.11), that the bar acts in concrete as a screw acts in wood, and that the act of twisting the rod cold increases the limit of stength from 30 to 60 percent as the fibers of the metal are drawn more closely together. This was the first successful system of reinforcing invented and used in America.

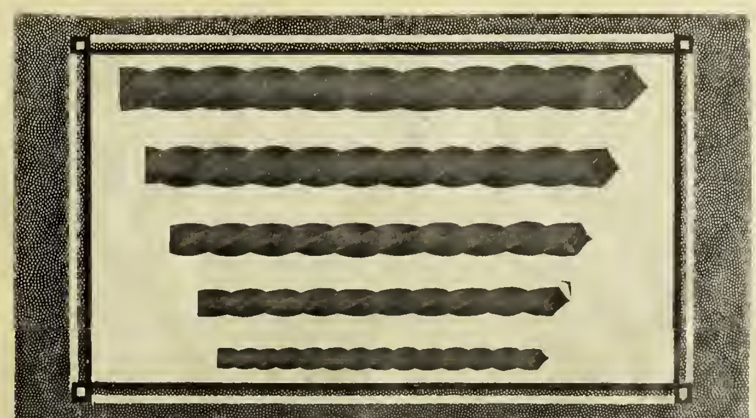


Fig. 11.

Mr. A. L. Johnson invented a corrugated bar with ribs nearly

at right angles to the axis of the bar. (See Fig. 12). Mr. Johnson believed that the amount, which this angle could be less than 90 degrees was not greater than the angle of friction of the materials used.

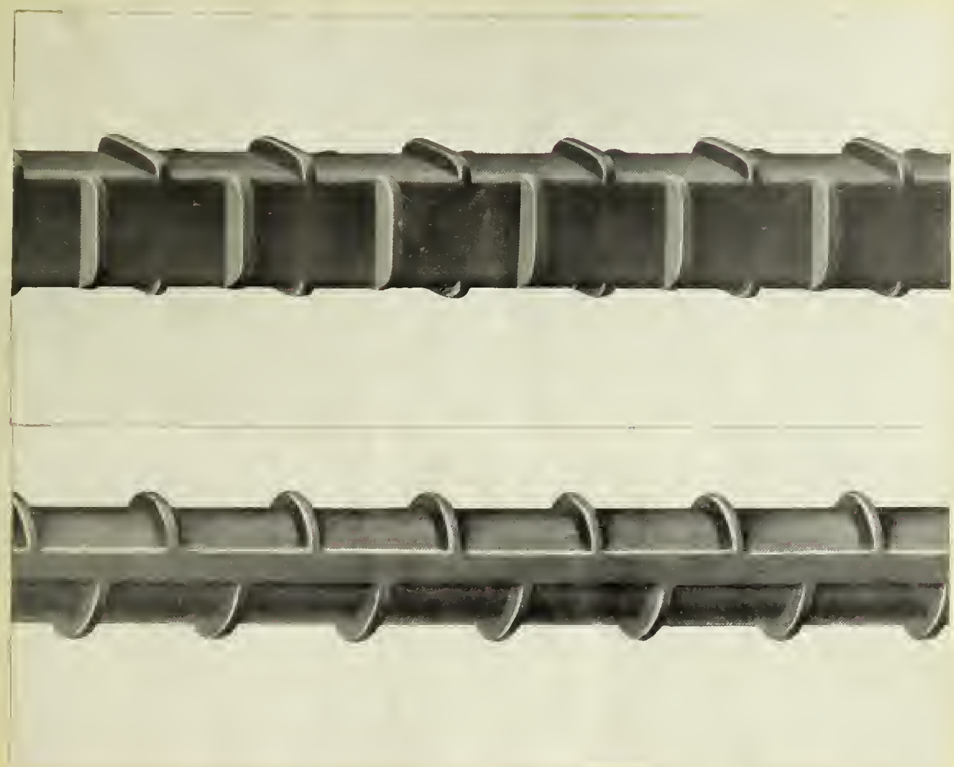


Fig. 12.

Bars are the most common kind of reinforcing used for highway bridge floors. Square, flat, and round bars are used to some extent but the patented Ransome twisted and Johnson corrugated bars are used to a far greater extent and give very satisfactory results.

ART. 6. THE "BAKER" REINFORCED CONCRETE FLOOR.

The "Baker" reinforced concrete floor (See Fig. 13) consists of one reinforced concrete slab covering the entire roadway. The

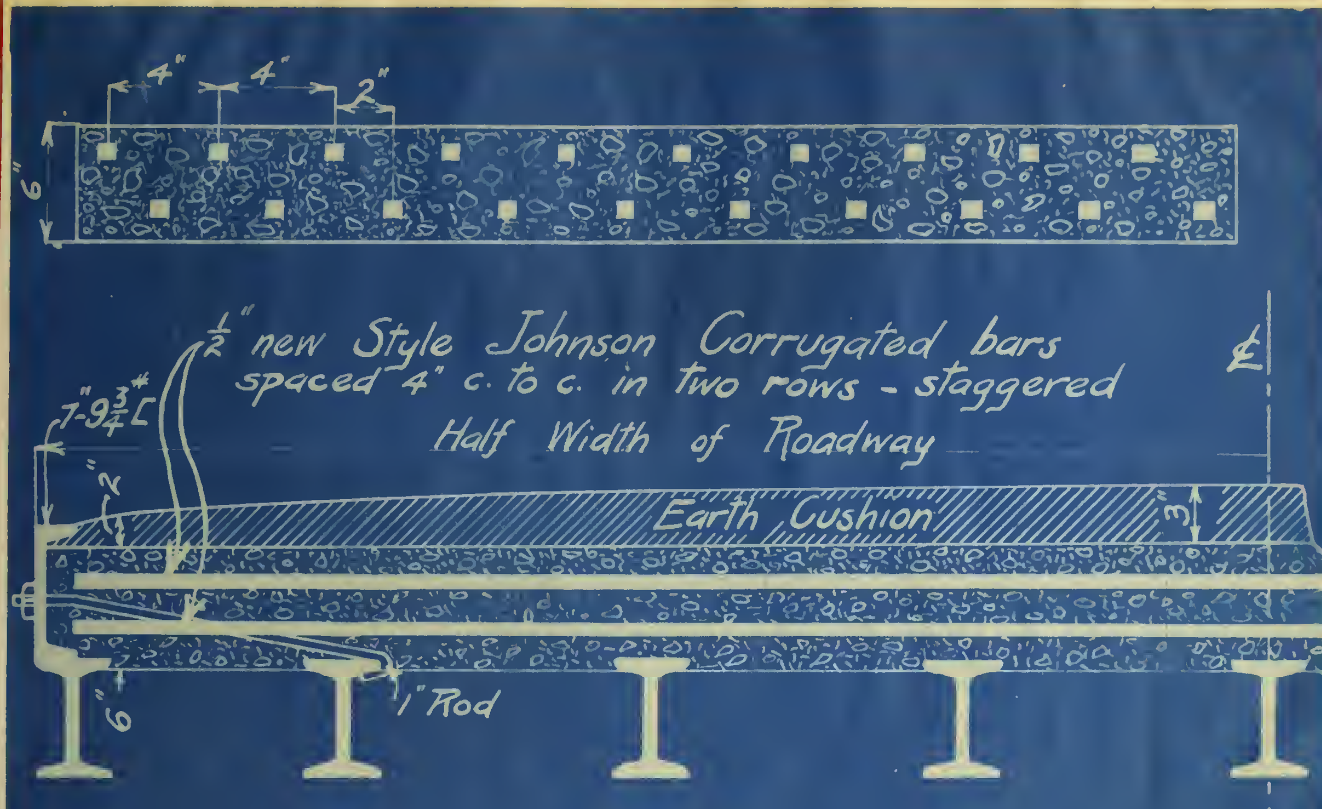


Fig. 13.

following extracts from the specifications for this floor give a clear idea of its composition and construction.

The Concrete. The concrete shall consist of 1 volume of any specified cement, 2 volumes of clean sand well graded from very fine to very large grains, and 4 volumes of pebbles or broken stone, the pieces of which range from 1/4 inch (1/4") to 1 inch (1"). The floor shall consist of a reinforced concrete slab 6 inches (6") thick with its lower face resting on the top of the joists. Special care is to be taken to bed the concrete around the reinforcement and not to displace the steel either horizontally or vertically.

The Reinforcement. The reinforcement shall consist of half-inch new style Johnson corrugated bars of a length 6 inches less than the clear roadway, spaced 4 inches (4") apart, laid at right angles to the joists. In addition there shall be a similar layer of corrugated bars 1 inch (1") below the top of the finished floor. A bar in the top series shall be in the

middle between two bars in the lower series.

Side Channel. At the sides of the roadway, the concrete shall be protected by placing a 7-inch 9-3/4 pound channel on the top of the outside joist. Said channel shall be bolted to the outside flange of the joist below by 5/8" bolts spaced three feet apart. Said channel shall rest against the truss at the panel points, and at the middle of the panel shall be tied at the center to the adjoining joist by a 1-inch rod hooked over the joist so as to prevent its being bowed outward by the tamping of the concrete.

Earth Cushion. After the concrete is completed a half-inch (1/2") layer of earth is to be scattered over the surface: and after the concrete has set for 7 days, earth is to be added until its depth at the center is 3 inches (3") and at the sides 2 inches (2").

The top row of reinforcing rods, often omitted in other designs, is put in to take up the tension caused by the floor slab acting as a continous beam over the joists. The "Baker" reinforced concrete floor is giving satisfactory service on all highway bridges on which it has been laid.

ART. 7. SPECIFICATIONS.

The specifications used are Cooper's "Specifications for Steel Highway Bridges," (Edition of 1901), except as noted below.

Dead Load. To be the weight of the superstructure complete.

Live Load. On steel trusses shall be assumed as follows in computing the stresses in all members and details.

For spans of 50 feet or less, a

uniform load of 125 pounds per square foot of floor area.

For spans over 50 feet and under 150 feet, a uniform load of 100 pounds per square foot of floor area.

For spans of 150 feet and over, a uniform load of 85 pounds per square foot of floor area.

For all spans a concentrated load of 15 tons, which shall be considered as supported on two axles, 10 feet centers, the rear axle to carry 10 tons and the forward axle 5 tons.

For all spans the live load stresses shall be increased by a percentage of the static live load stresses, found by the formula:

$$P = \frac{10,000}{L + 150}$$

where:

P = the percentage required, and
L = the length of span in feet or part of span covered by the live load when the member under consideration is subjected to its maximum stress.

No metal less than five sixteenth inch (5/16) thick shall be used in any member or detail of bridges except for fillers.

For Floor.

REINFORCED CONCRETE.

All reinforced concrete measuring less than six inches in thickness shall be made of Class A concrete (1-2 1/2-5) unless otherwise noted.

Unless otherwise shown on the drawings, all steel for reinforcement in concrete shall consist of bars which shall be twisted square section bars or which shall otherwise provide a rigid mechanical bond at frequent intervals.

Unless otherwise specified, all steel

2-5 [illegible]
the 2 [illegible]

for reinforced concrete shall be medium steel with an elastic limit of not less than 32,000 pounds per square inch. Steel bars shall withstand bending cold with a radius equal to twice their diameter through 180 degrees without fracture.

ART 8. DESIGN AND WEIGHTS OF BEAM BRIDGES.

Beam bridges of spans varying from 8 to 35 feet with "Baker" reinforced concrete floors were designed by the authors (See Plate I). The joists were spaced 2 feet 8 inches center to center. There are five I-beams and two channels. The following data was used in determining the dead load on these joists.

The weight of plain concrete was taken from Baker's "A Treatise on Masonry Construction," page 207, which gave 150 pounds per cubic foot.

The weight of the earth cushion was obtained from the same treatise on page 99, according to which rammed gravel weighs 145 pounds per cubic foot and has 20 percent voids which may be filled with water weighing 62.5 pounds per cubic foot. This gives a weight of (145 + 0.2 x 62.5) or 158 pounds per cubic foot for rammed gravel wet. Since the earth cushion has an average depth of 2 1/2 inches its weight per square foot of floor surface will be about 40 pounds. Adding 10 pounds to this on account of extra material that may be carried onto the bridge makes the total weight of the earth cushion approximately 50 pounds per square foot of floor surface.

The weight of the 1/2-inch Johnson corrugated reinforcing bars was found to be 0.86 pounds per linear foot of bar in the catalogue

Arrange some
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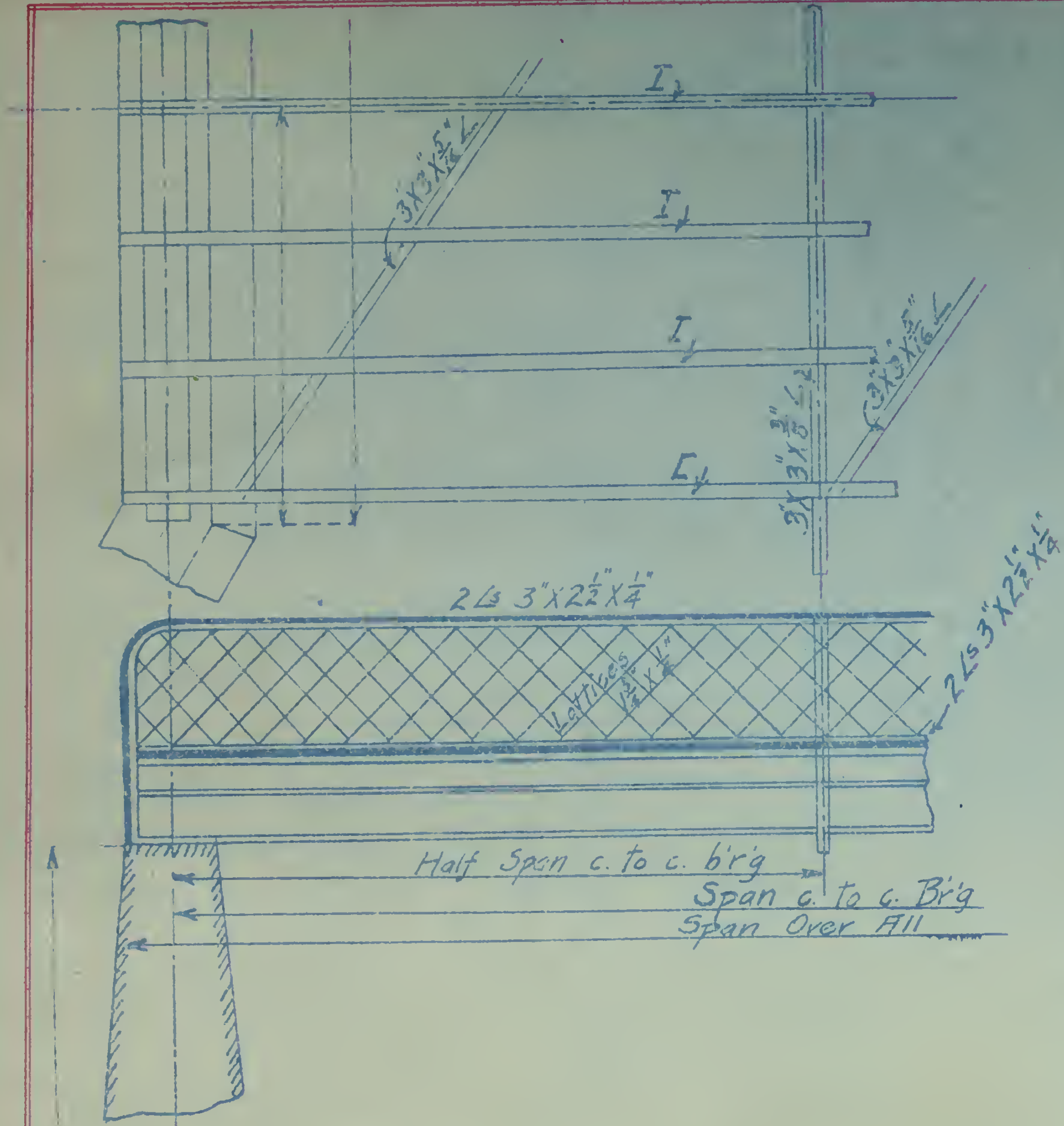
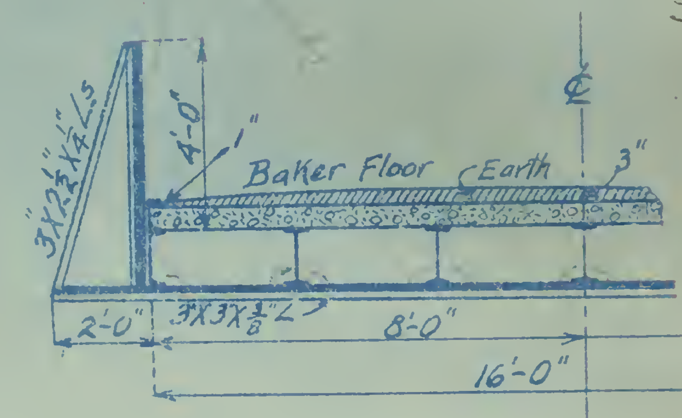
PLATE I

General Design of Beam Bridges





of the Corrugated Bar Company of Saint Louis, Missouri.

The live load on the joists was taken from the specifications (See page 17). The engine load on each wheel was considered to be distributed equally over three joists.

Bridges with a 2-foot spacing of joists were found, on investigation, to require more steel than those with a 2-foot 8-inch spacing, so for economy the latter spacing was used.

The break in the curve of Plate II, page 27at the 17-foot span is due to the engine position for maximum moment. For spans over 17 feet long the maximum moment occurs in the joists when the axle of the 10-ton wheels (See specifications, page 18) is 1.67 feet from the middle of the span. This brings the axle of the 5-ton wheels 0.17 feet from the end of the bridge. If the span was only 16 feet these wheels would be 0.33 feet off of the bridge and the maximum moment would then occur when the 10-ton wheels were moved to the middle of the bridge. However, the removal of the 5-ton wheels from the bridge causes a sudden drop in the maximum moment which in turn causes the break in the curve.

The weights of the bridges designed are given in Table I. Page 22.

TABLE I
Data and Weights of Beam Bridges

Reference Number	Span in Feet	Number and Spacing of Joists used	Joists		Weight of I-beams in pounds per foot	Weight of Channels in pounds per foot	Total Weight of Joists in pounds per foot of Span
			I beams	Channels			
1	8	Used 5 I-beams and 2 Channels spaced 2'-8" center to center	7"-15#	7"-9.75#	75.0	19.5	94.5
2	12		8"-18#	8"-11.25#	90.0	22.5	112.5
3	15		9"-21#	9"-13.25#	105.0	26.5	131.5
4	20		12"-31.5#	12"-20.50#	157.5	41.0	198.5
5	25		15"-42.0#	15"-33.00#	210.0	66.0	276.0
6	30		18"-55.0#	15"-33.00#	275.0	66.0	341.0
7	35		20"-65.0#	15"-45.00#	325.0	90.0	415.0

ART. 9. DESIGN AND WEIGHTS OF PONY BRIDGES.

The pony bridges used in this thesis were obtained from the Illinois State Highway Commission through the courtesy of Mr. A. N. Johnson, State Engineer. The spans varied from 35 to 75 feet and the height of trusses from 6 feet 6 inches to 9 feet. The heights, however, do not affect the weights of bridges of equal spans as may be seen from a glance at Table II, Column 6.

The design of the floors used in these bridges is shown in Fig. 14. The concrete was assumed to weigh 150 pounds per cubic foot, and the reinforcing bars 0.86 pounds per foot, the same as in the beam bridges. The earth cushion was assumed to be 50 pounds per square foot of floor surface although it is much deeper than that on the "Baker" floor in which the same weight of cushion was

assumed.

The live load was taken from the specifications, page 18 . The engine load on each wheel was considered to be equally distributed over three joists.

The weights of the bridges used are given in Table II.

TABLE II
Data and Weights of Pony Bridges

Reference Number	Span in Feet	Height of Truss in Feet and Inches	Total Weight of Trusses in Pounds	Total Weight of Stringers and Floorbeams in Pounds	Total Weight of Steel in Bridge in Pounds	Weight of Trusses in Pounds per Foot of Span	Mean Weight of Trusses in Pounds per Foot of Span
1	36	6-6	8,893	8,107	17,000	247	247
2	40	7-0	10,383	8,393	18,776	259	259
3	50	7-0	13,250	11,500	24,750	265	271
3	50	7-0	13,831	11,039	24,870	277	
4	60	8-0	19,989	12,711	32,700	333	292
4	60	7-6	16,960	13,240	30,200	282	
4	60	10-0	18,800	12,300	31,100	313	
5	70	9-0	24,275	15,425	39,700	347	347
6	75	9-0	27,590	16,380	43,970	369	369

ART. 10. DESIGN AND WEIGHTS OF TRUSS BRIDGES.

The truss bridges used were of two different kinds. Table III gives the data and weights of those designed by the Illinois State Highway Commission with the floor shown in Fig. 14. Table IV gives the data and weights, as computed by the authors, of bridges

TABLE III
Data and Weights of Truss Bridges with "Johnson" Floor

Reference Number	Span in Feet	Height of Truss in Feet and Inches	Total Weight of Trusses in Pounds	Total Weight of Stringers and Floor-beams in Pounds	Total Weight of Steel in Bridge in Pounds	Weight of Trusses in Pounds per Foot of Span	Mean Weight of Trusses in Pounds per Foot of Span
1	75	17-0	26,970	17,720	44,690	360	368
1	75	17-0	28,295	16,380	44,675	377	
2	80	17-0	30,138	18,362	48,500	377	377
3	90	18-0	37,876	21,222	59,098	421	397
3	90	18-0	33,509	18,491	52,000	373	
4	100	20-0	41,954	22,270	64,224	419	419
5	120	22-0	57,692	26,308	84,000	481	481
6	140	24-0	74,962	30,138	105,100	536	525
6	140	24-0	71,758	32,742	104,500	514	
7	160	27-0	91,730	37,870	129,600	573	573

TABLE IV
Data and Weights of Truss Bridges with "Baker" Floor

Reference Number	Span in Feet	Height of Trusses in Feet and Inches	Total Weight of Trusses in Pounds	Total Weight of Stringers and Floor-beams in Pounds	Total Weight of Steel in Bridge in Pounds	Weight of Trusses in Pounds per Foot of Span	Mean Weight of Trusses in Pounds per Foot of Span
1	80	16-0	21,525	24,943	46,468	269	269
2	120	24-0	43,311	32,388	75,699	361	361
3	144	24-0	59,930	34,344	94,264	417	417
4	160	24-0	80,430	44,924	125,354	502	502

with a "Baker" floor. (See Fig. 13). The trusses in all the bridges were of the Pratt type.

The dead and live loads used were found in the same manner as described for pony bridges on page 22.

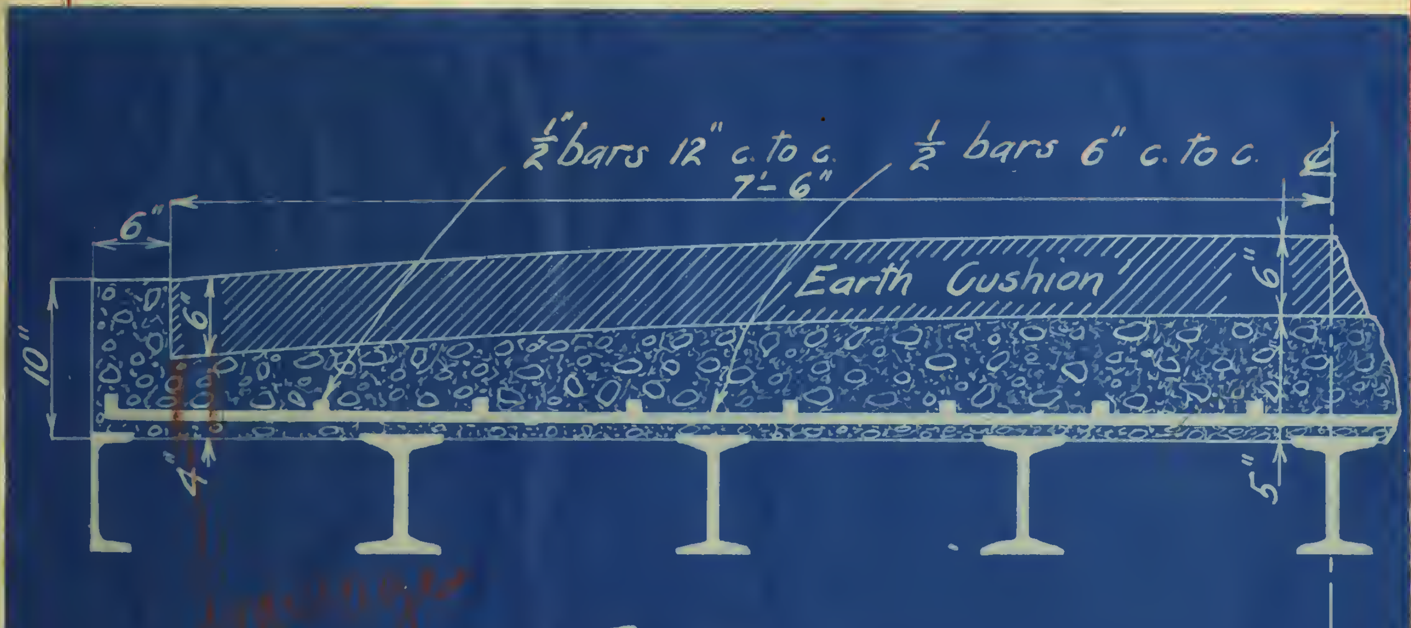


Fig. 14

ART. 11. THE EMPIRICAL FORMULAE.

Formulae were derived for the weight of steel per foot of span in:

1. The beam bridges of Table I and Plates I and II,
2. The pony bridges of Table II and Plate III, and
3. The truss bridges of Tables III and IV, and Plates IV and V.

All of these formulae were derived by the use of the general equation of the conic section which is:

$$y = a + bx + cx^2 + dx^3 \text{ - - - - - - - - - - - - - - } (1)$$

where $y = w$ or the weight per foot of span in the joists for 1 and in the two trusses for 2 and 3,

$x = L$ or the length of span of the bridge in feet and a, b, c and d are constants depending on the shape of the curves of Plates II, III, IV, and V.

For the beam bridges it was necessary to derive two formulae on account of the break in the curve of Plate II already described on page 21. The (x, y) coordinates of the points used in determining the constants a, b, c, and d for spans under 17 feet were (0, 70), (8, 95), (12, 113) and (15, 132). The probable point of intersection of the curve with the Y-axis (in this case (0, 70)) was used as one of the points in determining each of the curves derived, because it was found that on taking four points of the curve, the derived curve had the lowest point of these four as its vertex from which it curved upward to the left thus giving increasing values of w for decreasing values of L which from inspection is not correct.

Substituting the above four points in equation (1) gives:

$$70 = a + 0 \text{ - - - - } 113 - 70 = 12b + 144c + 1728d$$

$$95 - 70 = 8b + 64c + 512d$$

$$132 - 70 = 15b + 225c + 337d$$

Solving these equations simultaneously gives the following values:

$$a = +70$$

$$b = +3.126$$

$$c = -0.0819$$

$$d = +0.00982$$

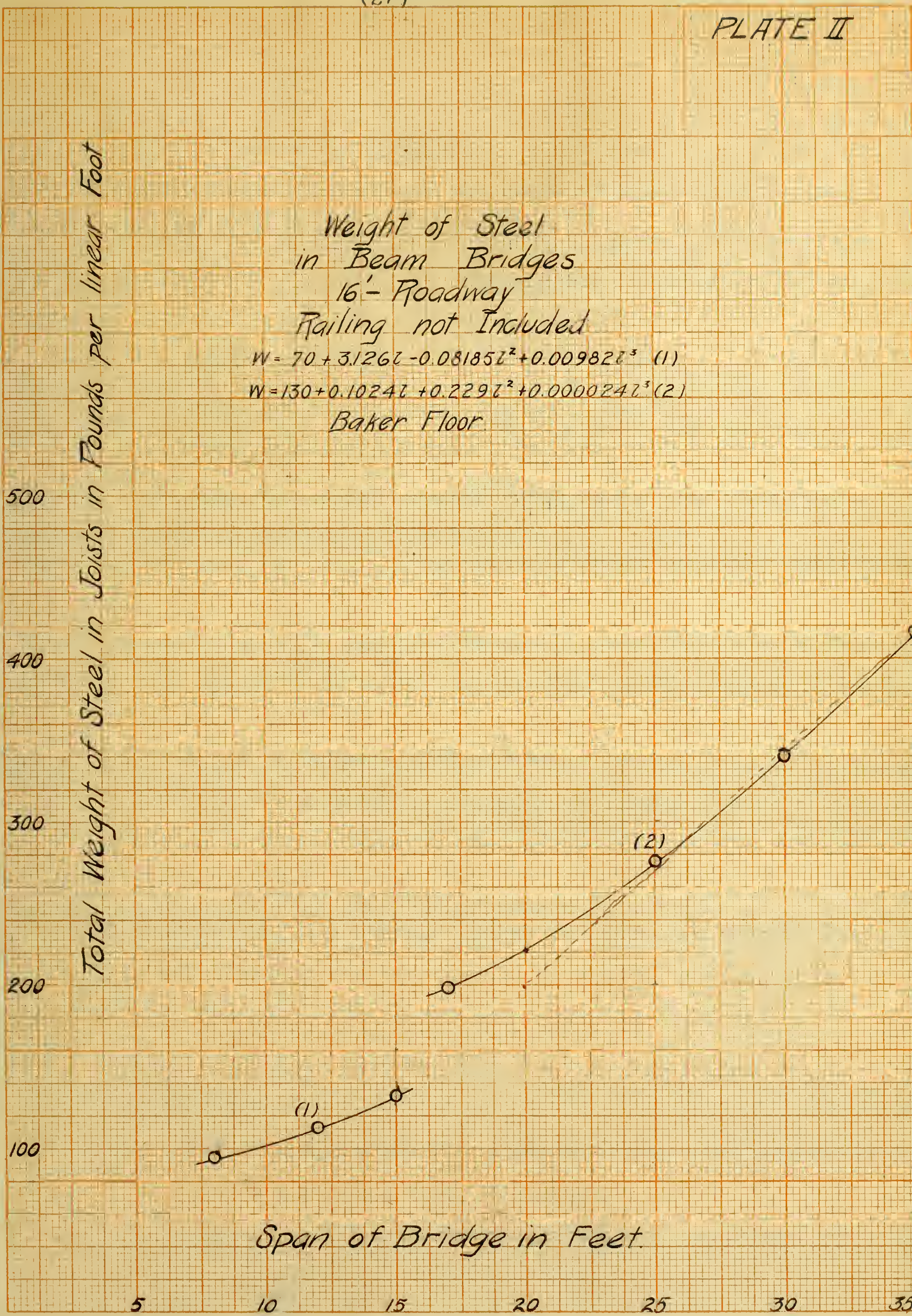


PLATE II
Weight of Steel
in Beam Bridges
16'- Roadway
Railing not Included
W = 70 + 3.126l - 0.08185l² + 0.00982l³ (1)
W = 130 + 0.1024l + 0.229l² + 0.000024l³ (2)
Baker Floor
Total Weight of Steel in Joists in Pounds per linear Foot
500
400
300
200
100
(1)
(2)
Span of Bridge in Feet
5
10
15
20
25
30
35

Substituting these back in equation (1) gives:

$$w = 70 + 3.126L - 0.0819L^2 + 0.00982L^3$$

The points used in deriving the curve of Plate II for spans of 17 feet and over have the following coordinates, (0,130), (17, 198), (25, 276) and (35, 415). Substituting in equation (1) as before:

$$130 = a + 0 \text{ -----}$$

$$198 - 130 = 17b + 289c + 4{,}913d$$

$$276 - 130 = 25b + 625c + 15{,}625d$$

$$415 - 130 = 35b + 1{,}225c + 42{,}875d$$

Solving the above equations simultaneously:

$$a = +130$$

$$b = +0.102$$

$$c = +0.2289$$

$$d = +0.000024$$

Substituting again in equation (1) gives:

$$w = 130 + 0.102L + 0.2289L^2 + 0.000024L^3$$

The curves of these formulae were drawn and found to fit the original ones accurately.

The formula for the curve of Plate III for pony bridges was derived by substituting the coordinates of the following points in equation (1), (0, 225), (40, 250), (60, 300), and (75, 370), and solving for the constants a, b, c and d. This gives:

$$225 = a + 0$$

$$250 = a + 40b + 1600c + 64{,}000d$$

$$300 = a + 60b + 3600c + 216{,}000d$$

$$370 = a + 75b + 5{,}625c + 421{,}875d$$

or

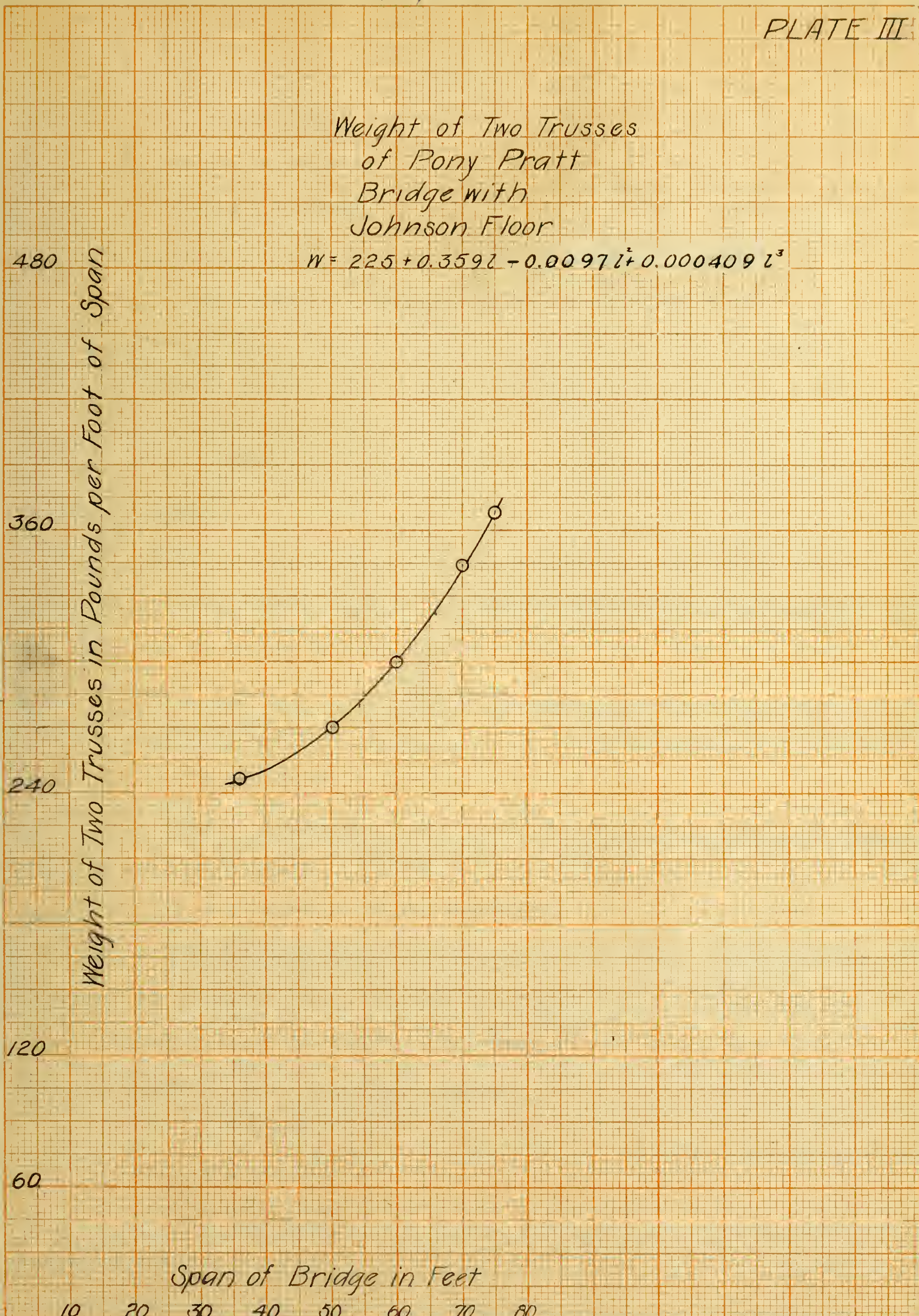


PLATE III
Weight of Two Trusses
of Pony Pratt
Bridge with
Johnson Floor
W = 225 + 0.359 l − 0.0097 l² + 0.000409 l³
Weight of Two Trusses in Pounds per Foot of Span
480
360
240
120
60
Span of Bridge in Feet
10
20
30
40
50
60
70
80

$a = +225$

$b = +0.359$

$c = -0.0097$

$d = +0.000409$

which on substitution back in equation (1) give:

$$w = 225 + 0.359L - 0.0097L^2 + 0.000409L^3$$

The curve of this equation checked exactly with the original.

In a similar manner the equation of the curves were found for:

(a) Plate IV.

(b) Plate V.

of truss bridges.

The curve of Plate IV is for the weights of two Pratt trusses per foot of span for bridges with "Baker" floors and its equation was obtained by using the points (80, 269), (120, 361) and (160, 502). These points give for equation (1):

$a = +230$

$b = -0.75$

$c = +0.0153$

which substituted make:

$$w = +230 - 0.75L + 0.0153L^2$$

Plate V shows the curve for the weights of two Pratt trusses per foot of span for bridges with the floor shown in Fig. 14, page 25. Substituting the points (75, 368), (100, 419), and (160, 573) in equation (1) as before shows:

$a = +262$

$b = +0.975$

$c = +0.0062$

making equation (1) become

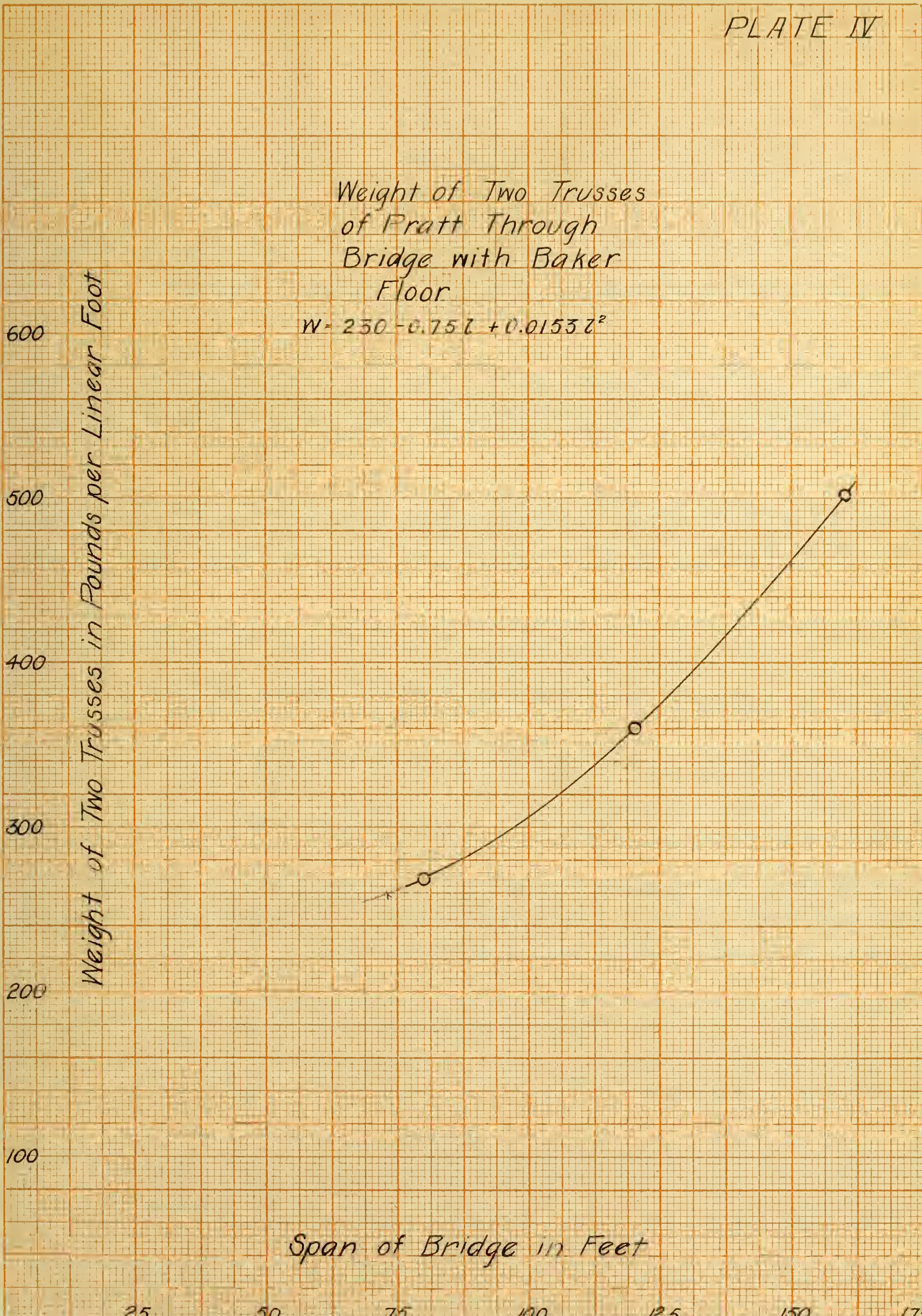


PLATE IV
Weight of Two Trusses
of Pratt Through
Bridge with Baker
Floor
W = 250 - 0.75 l + 0.0153 l²
Weight of Two Trusses in Pounds per Linear Foot
600
500
400
300
200
100
Span of Bridge in Feet
25
50
75
100
125
150
175
U. OF I. S. S. FORM 3

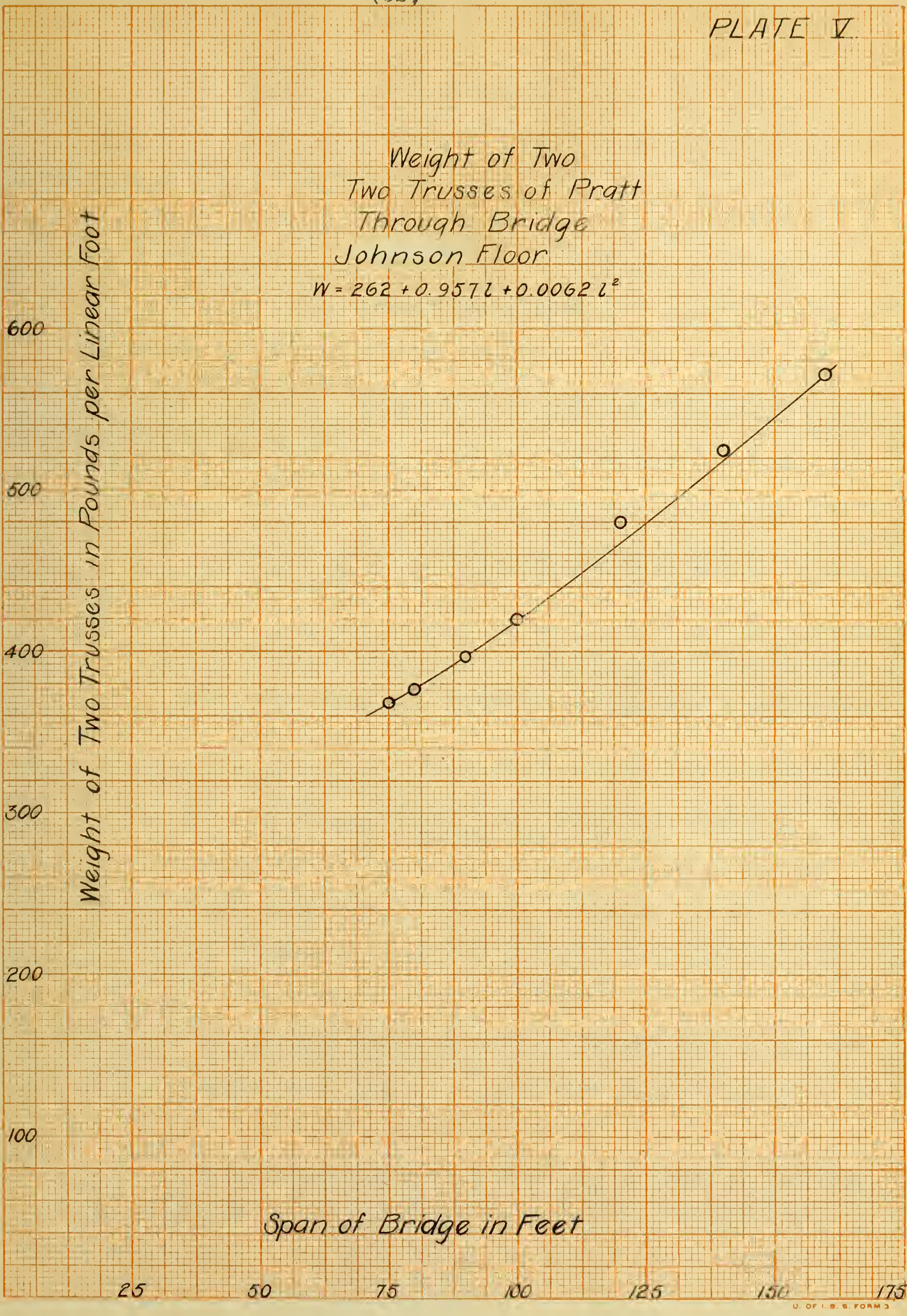


PLATE V.
Weight of Two
Two Trusses of Pratt
Through Bridge
Johnson Floor
W = 262 + 0.957 l + 0.0062 l²
Weight of Two Trusses in Pounds per Linear Foot
600
500
400
300
200
100
Span of Bridge in Feet
25
50
75
100
125
150
175
U. OF I. S. S. FORM 3

$$w = +262 + 0.957L + 0.0062L^2$$

Both of the above formulae gave curves which checked with the originals.

ART. 12. SUMMARY OF WEIGHTS.

In designing Class B bridges according to the specifications of Art. 7, the following dead load weights may be used for the different types of bridges:

1. Beam bridges,

$$w = 70 + 3.126L - 0.08185L^2 + 0.00982L^3$$

for spans up to and including 16-feet and,

$$w = 130 + 0.1024L + 0.229L^2 + 0.000024L^3$$

for spans varying from 17 to 40 feet, where 'w' is the total weight of steel in the joists in pounds per foot of span.

2. Pony trusses,

$$w = 225 + 0.359L - 0.0097L^2 + 0.000409L^3$$

where 'w' is the total weight of steel in the two trusses in pounds per foot of span.

3. Truss bridges,

$$w = 230 - 0.75L + 0.0153L^2$$

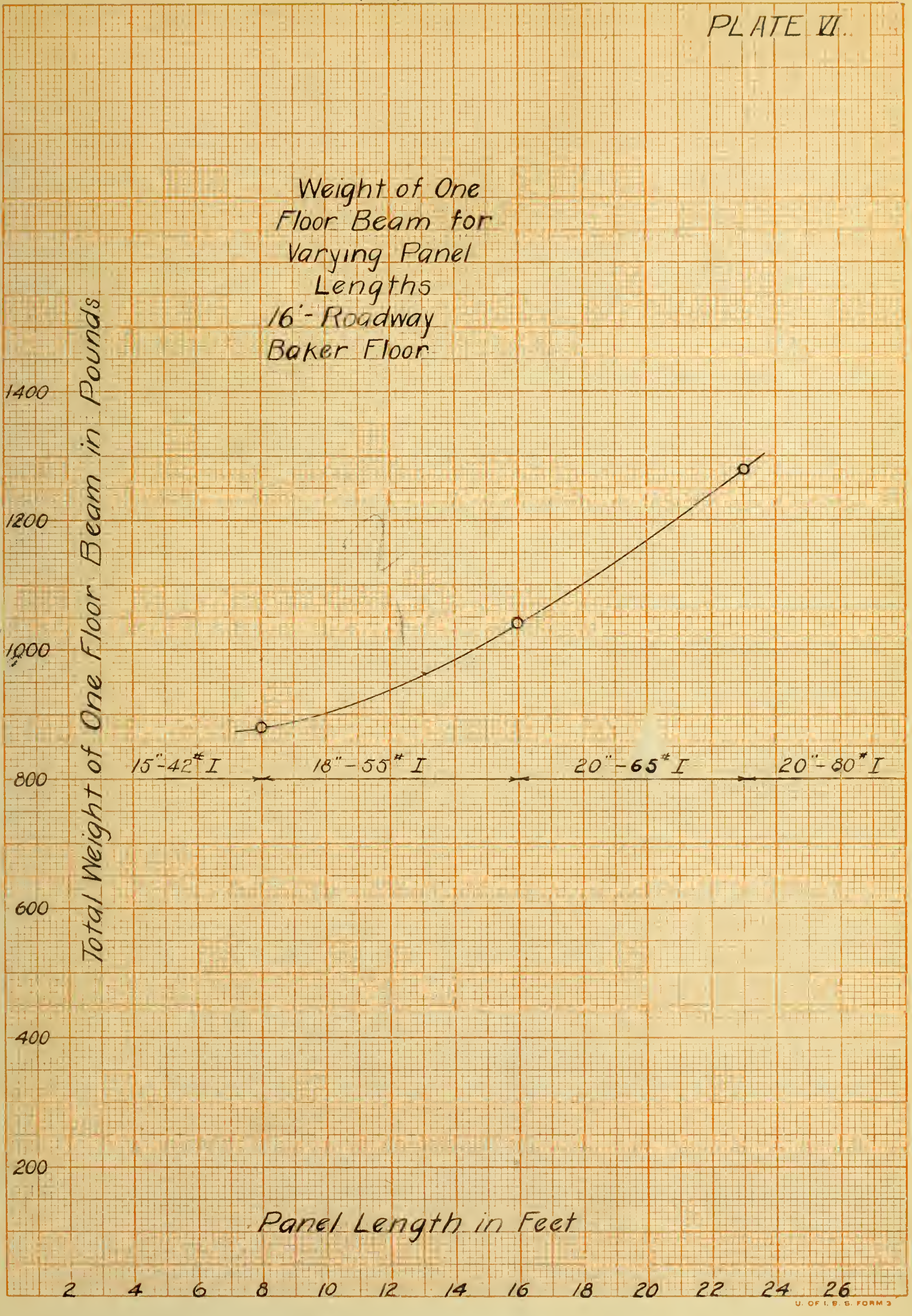
for bridges designed for the "Baker" Reinforced Concrete floor, and

$$w = 262 + 0.957L + 0.0062L^2$$

for bridges designed for the floor shown in Fig.14.

The weight of joists and floor beams may be obtained from Plates VI and VII. In Plate VI the weight of one floor beam for

PLATE VI.



U. OF I. S. S. FORM 3

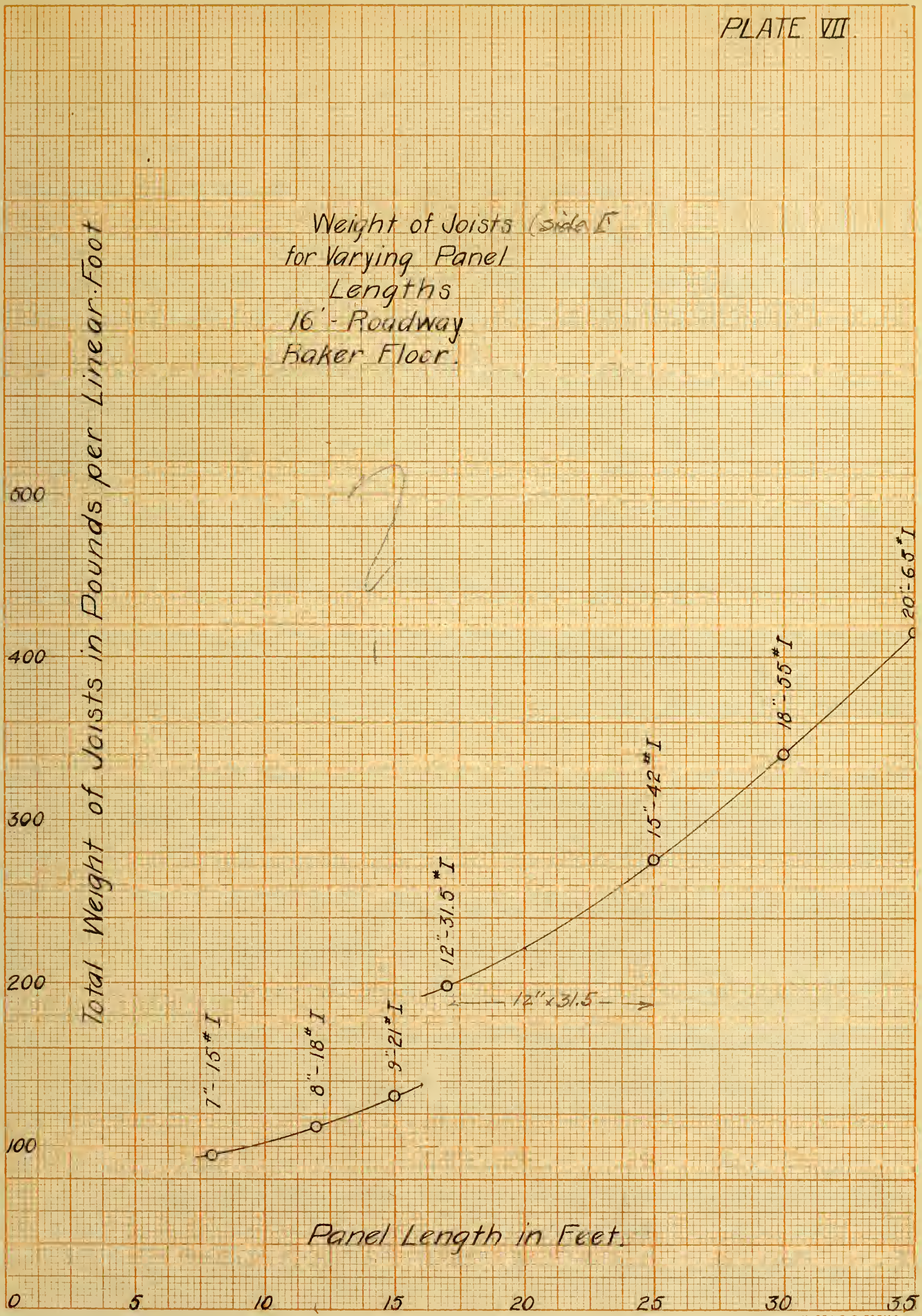


PLATE VII.
Weight of Joists (side I
for Varying Panel
Lengths
16' - Roadway
Baker Floor.
Total Weight of Joists in Pounds per Linear Foot
Panel Length in Feet.
7" - 15# I
8" - 18# I
9" - 21# I
12" - 31.5# I
12" x 31.5
15" - 42# I
18" - 55# I
20" - 65# I
100
200
300
400
500
0
5
10
15
20
25
30
35
U. OF I. S. S. FORM 3

varying panel lengths, is given in pounds. The minimum panel length for each standard I-beam was computed, and the curve was then plotted from the points obtained as shown.

Dead load weight of reinforced concrete floor is practically 80 pounds per square foot of floor surface for the "Baker" floor, and approximately 65 pounds per square foot for the floor used by the Illinois State Highway Commission, ("Johnson").

For the earth cushion 50 pounds per square foot of floor surface may be added.

ART. 13. CONCLUSIONS.

The total weight of any bridge may be found by adding the following:

(1). w (from the proper formula) multiplied by the span in feet.

(2). weight of joists (from Plate VII) multiplied by the span in feet.

(3). weight of one floor beam (from Plate VI) multiplied by the number of panels minus one.

(4). the sum of the weights of the reinforced concrete floor and of the earth cushion per square foot of floor, multiplied by the floor area in square feet.